

Using companion plants to assist *Pinus patula* establishment on former agricultural lands

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Abstract

Companion or nursing taxa may aid the establishment of agricultural and forestry crops by improving soil N status (if legume) and soil structure, and by reducing soil erosion and suppressing weedy species. This study's objectives were to test the applicability of soybean and weeping love grass as companion plants for assisting *Pinus patula* establishment on former agricultural lands (oldlands), and their capacity for suppressing growth of weedy species. Two experimental trials were conducted which involved growing pine, soybean, weeping love grass and an assortment of weedy species in monocultures and mixtures in pots containing oldland and plantation soils. Pine height and stem diameter were measured at monthly intervals, with total biomass accumulation in all taxa determined 14 months after planting. In the presence of soybean, both shoot and root growth of pine seedlings were enhanced, but root growth was reduced in the presence of weeping love grass. In the presence of the weedy species assortment, pine stem diameter, height, shoot and root biomass were all decreased. In contrast, total biomass accumulation of both soybean and weeping love grass was unaffected by the presence of the weed species assortment. However, the total biomass of this assortment was reduced in the presence of these two species. It is concluded, that *P. patula* establishment on oldlands infested with agronomic weeds may be improved by cultivating this species together with soybean.

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1. Introduction

The rapid increase of commercially afforested areas in South Africa has necessitated planting on both natural grassland and former agricultural lands (oldlands). However, planting *Pinus patula* and *P. elliotti* on oldlands has been reported unsuccessful while plantings on natural grasslands were successful (Schumann and Noble, 1993). This phenomenon is referred to as the 'oldland syndrome' (Reinhardt et al., 1999). Agricultural lands were originally cropped with maize (*Zea mays* L.), oats (*Avena sativa* L.) and wheat (*Triticum aestivum* L.) (Noble and Schumann, 1993). A distinctive characteristic of these former agricultural lands is the multitude of different weed species. When pine seedlings are planted on these lands, the seedlings are exposed to interference from weeds. Previous research has documented both the competition and allelopathic effects of

weeds on pine seedling growth and establishment (Smith, 1989; Nilsson et al., 1993; Little and Rolando, 2001; Bezuidenhout, 2001).

Poor survival of hardwood seedlings in weedy abandoned fields has been problematic for decades (Fisher, 1987). Smith (1989) found that the rates of stem diameter and height increases were reduced for pine seedlings planted in broom-sedge (*Andropogon virginicus* L.), bermudagrass (*Cynodon dactylon* (L.) Pers.) and tall fescue (*Lolium arundinaceum* (Schreb.) stands. Eccles et al. (1997) reported a 33% biomass reduction of *P. patula* seedlings in weedy plots and a mean pine mortality frequency of 8% as opposed to a mortality frequency of only 1.7% in weed-free plots.

Weed management has been shown to increase pine growth and timber yield (Nilsson et al., 1993; Gous, 1995, 1996). In pine plantations, herbicides and manual labour are the main weed control methods used (Gous, 1996), which may become very expensive. Biological methods of controlling weeds are of increasing interest world-wide in efforts to reduce the use of chemicals. Usually pathogens that affect

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certain weeds are used for biological weed control; the nearest potential biological element – the crop itself – is often not considered (Doll et al., 1995). Reducing herbicide inputs by using properly managed cover crops could be of great benefit to the agricultural sector while ensuring sustainability (White et al., 1989; Yenish et al., 1996). Plants with high competitive ability against weeds can be used to suppress weeds, and legumes are preferable as they also supply N (Hartl, 1989). Additional advantages of cover crops may include improved soil structure, reduced erosion and conservation of leachable nutrients (Holderbaum et al., 1990). A suitable cover crop, which would not interfere with the desired crop, should be chosen. Schumann (1992) found cowpea (*Vigna sinensis*) to be suitable as a cover crop for *Eucalyptus* stands older than 3 months, while velvet bean (*Mucuna pruriens*) was found unsuitable due to its high competitive effects on seedlings.

The objectives of this study were to determine (1) whether soybean or weeping love grass could be used as a companion crop to assist *P. patula* establishment on oldlands, and (2) quantify the weed suppressive abilities of soybean or weeping love grass.

2. Methods and materials

2.1. Treatments and growing conditions

Two trials were conducted at the Hatfield Experimental Farm, University of Pretoria between March 1997 and May 1998, each comprising 5 treatments. In the first trial, *P. patula* seedlings were grown in monocultures on plantation and oldland soils and in mixtures with soybean, weeping love grass and an assortment of weedy species sourced from the old land soils. In the second trial, soybean and weeping love grass and the weedy species assortment were grown separately and in mixtures on oldland soils. In each trial, a completely randomized design was adopted with each treatment comprising 10 replicates with the exception of the treatment containing the weedy species assortment in the first trial, which only had four replicates.

Oldland and plantation soils for the trials were collected from Mondi Forests Giant's Castle Estate at Mooi River, KwaZulu-Natal, the plantation soil supporting a 7-year old *P. patula* stand. Soils were dried and sieved prior to their use in the trials. Their physical and chemical properties are presented in Table 1. Pots were filled with 4.8 kg of soil (3 kg in the second trial) and watered to field capacity by adding 250 ml of water every 4th day to the pots initially. Later the frequency of this application was increased to every 2nd day due to an increased water requirement of the growing plants. Pine seedlings (1 seedling

pot⁻¹) of uniform (approximately 10 cm) height were introduced into the pots at the commencement of the first trial (25th of March 1997). Soybean (Pannar 577G) and weeping love grass (Ermelo type) seeds were sown into the pots in both trials; 5 weeks later, their seedling densities reduced to 4 and 20 plants pot⁻¹, respectively. No nutritional supplements were supplied during the course of the trials. Weedy contaminants were removed manually in all the treatments except those comprising the weedy species assortment. Red spider mite infestations on soybean were controlled with tetradifon (Red spidercide). Approximately 7 months after commencement of the first trial, the weeping love grass and the weedy species in the weedy assortment treatment were cut to a height of 2 and 10 cm, respectively above the soil surface to reduce competition for light with the residual plant material left on the soil surface. Soybeans in the first trial were cut after 4 months growth, and the residual plant material also left on the soil surface. Weeping love grass was killed with a glyphosate application 12 months after sowing.

2.2. Plant growth and biomass accumulation

In the first trial, measurements of pine stem diameter and height and counts of the numbers of auxiliary shoots commenced 4 months after planting and continued at monthly intervals. After 14 months growth, plants were harvested from each pot, sorted into shoot and root fractions and their fresh and dry mass determined, the latter following drying of plant material to a constant mass in a forced draft oven.

In the second trial, the total numbers of weeds that emerged from the oldland soils in each pot were counted. Above-ground parts of all plants in the pots were harvested after three months growth, sorted into species and weighed following drying of plant material to a constant mass in a forced draft oven.

2.3. Statistical analysis

An analysis of variance using Statistical Analysis System (1989) (SAS/STAT® User's guide. Version 6, 4th ed. Cary, NC: SAS Institute Inc) tested for differences between treatments in the two trials. Significantly different treatment means were separated with a least significant difference test at $P \leq 0.05$.

3. Results

3.1. Pine stem diameter

Significantly ($P \leq 0.05$) smaller stem diameters were measured in pine seedlings grown in the presence than

Table 1
Physical and chemical properties of plantation and oldland soil collected at the Mondi Forest's Giant Castle Estate at Mooi River

Soil	pH (H ₂ O)	C %	Bray I P mg kg ⁻¹	Ca mg kg ⁻¹	K mg kg ⁻¹	Mg mg kg ⁻¹	Na mg kg ⁻¹	B mg kg ⁻¹
Plantation	5.69	3.60	5.07	203.3	159.0	157.0	11.2	0.34
Oldland	5.86	3.74	15.48	242.0	186.0	87.0	9.3	0.30

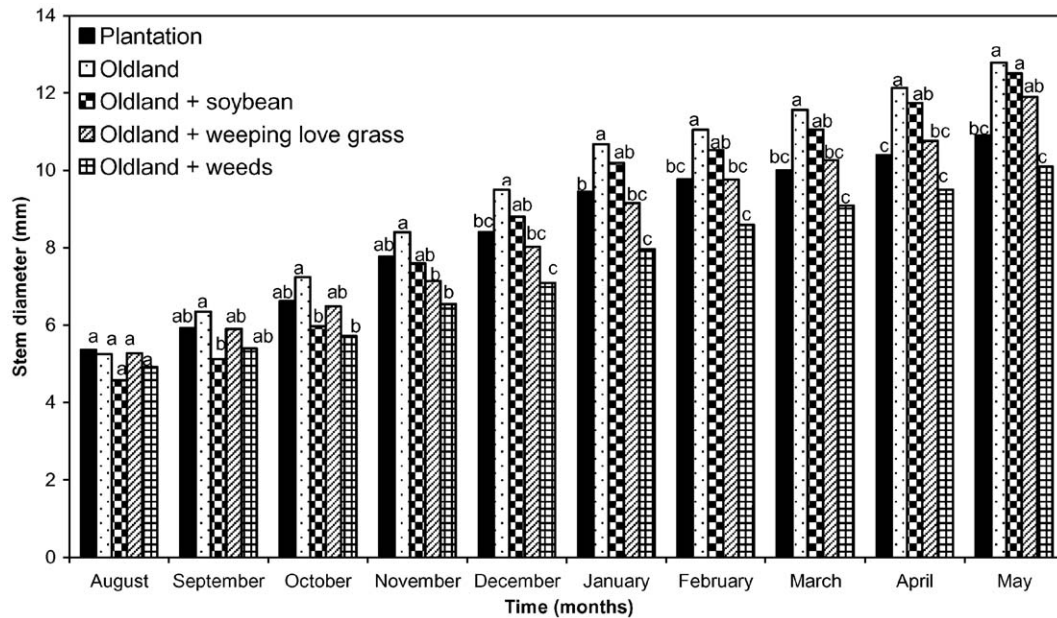


Fig. 1. Stem diameter of pine seedlings grown in monocultures and mixtures with soybean, weeping love grass and a weedy species assortment on oldland and plantation soils over a 10 month (August 1997 to May 1998) period. Bars associated with the same letter within each group month not significantly different at $P \leq 0.05$.

absence of soybean on oldland soils (Fig. 1), these smaller diameters apparent only during September and October when the companion soybean was in an actively growing state. Similarly, smaller ($P \leq 0.05$) stem diameters were consistently observed in pine seedlings grown in the presence than in the absence of weeping love grass and the weedy species assortment on the old land soils except during the first three months of measurement. Noteworthy, also was an

observed greater ($P \leq 0.05$) stem diameter in pine seedlings grown in monoculture on the oldland than plantation soils during the last 6 months of the trial (Fig. 1).

3.2. Pine height and branching

Significantly ($P \leq 0.05$) greater heights were observed in pine seedlings grown in mixtures with soybean than in mixtures

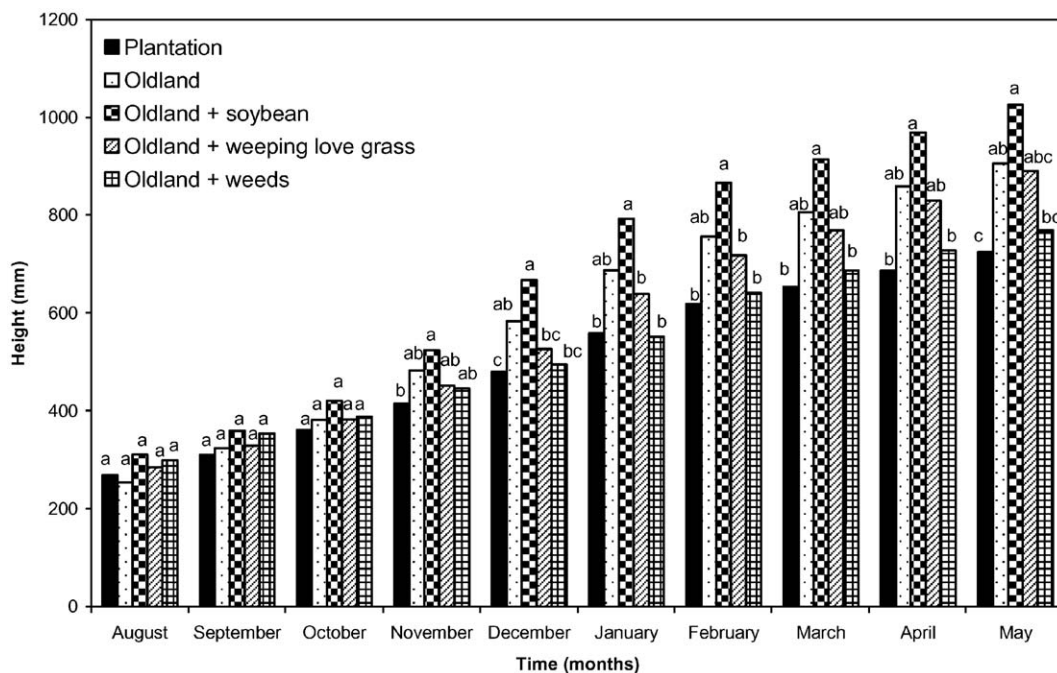


Fig. 2. Heights of pine seedlings grown in monocultures and mixtures with soybean, weeping love grass and a weedy species assortment on oldland and plantation soils over a 10 month (August 1997 to May 1998) period. Bars associated with the same letter within each group month not significantly different at $P \leq 0.05$.

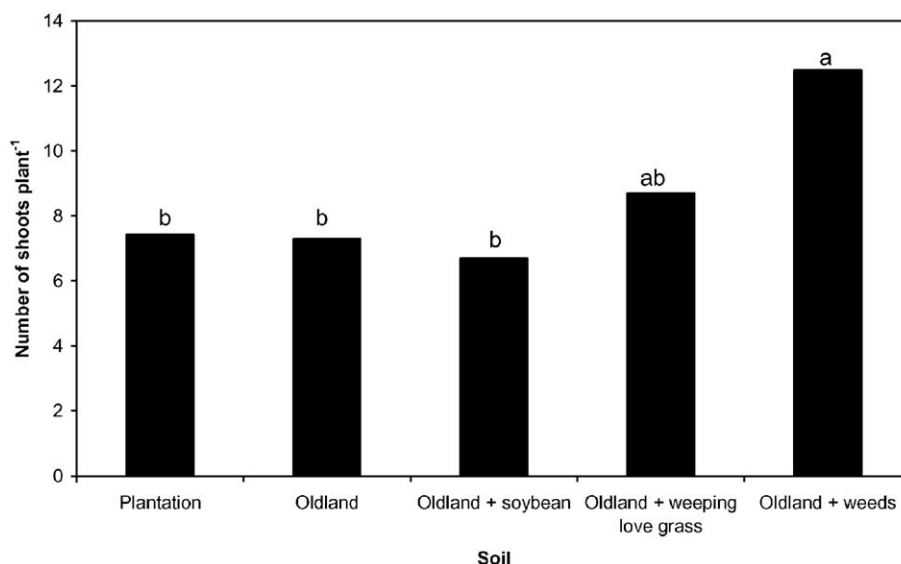


Fig. 3. Number branches produced by pine seedlings in response to different soil treatments. Bars associated with the same letter were not significantly different at $P \leq 0.05$.

with weeping love grass and the weedy species assortment during intermediate stages (between December and February) of the trial (Fig. 2). During later stages (last 3 months) of the trial, pine seedling heights grown in presence of soybean were only significantly ($P \leq 0.05$) greater than those grown in the presence of the weedy species assortment on the oldland soils. Like stem diameter, generally greater pine seedling heights were observed in pine seedlings grown in monoculture on the oldland than plantation soils, but these were only statistically significant ($P \leq 0.05$) in the last month of the trial. Pine seedlings exhibited no significant ($P \geq 0.05$) differences in branching (side shoot production) in the different treatments (Fig. 3) except in the presence of the weedy species assortment on the oldland soils where branching was significantly ($P \leq 0.05$) greater averaging 13 shoots plant⁻¹ compared with under 9 shoots plant⁻¹ in the other treatments.

3.3. Pine shoot and root biomass

Pine seedlings produced the smallest ($P \leq 0.05$) shoot biomass when grown in mixture with the weedy species assortment on the oldland soils and in monoculture on the plantation soils (Table 2). The second smallest ($P \leq 0.05$) aboveground (shoot) biomass was produced by pine

seedlings grown in mixture with weeping love grass, but pine seedlings grown in mixture with soybean displayed no significant ($P \geq 0.05$) alterations in shoot biomass. Significantly ($P \leq 0.05$) reduced below-ground (root) biomasses of pines were only observed where seedlings were grown in mixture with weeping love grass and the weedy species assortment on the oldland soils (Table 2).

3.4. Soybean and weeping love grass interference

The spectrum of weedy species that emerged from the oldland soils comprised mainly *Digitaria sanguinalis*, *Amaranthus* species, *Datura ferox*, *Solanum nigrum*, and a *Helichrysum* spp with the more common weedy species that normally emerge from these soils, namely *Cyperus esculentus*, *Conyza sumatrensis* and *Bidens pilosa* sparsely present. The presence of soybean and weeping love grass on the oldland soils had no significant ($P \geq 0.05$) detrimental effect on the total abundance of weedy species that emerged from these soils but did significantly ($P \leq 0.05$) reduce the weedy species assortment total biomass by 61% and 88%, respectively. Conversely, aboveground biomasses of both soybean and weeping love grass were unaffected ($P \geq 0.05$) by the weedy species assortment.

4. Discussion

Improved pine seedling growth on the weed-free oldland soil was attributed to the elimination of competition and allelopathy. These results concur with previous research, which has reported increases in stem diameters of *P. taeda* (Quicke 1995 ex Gous, 1996) and *P. radiata* (Gous, 1995) in oldland soils where weeds were removed. However, there do exist other potential causes for the observed improvement of pine seedling growth on oldland soils, often referred to as “oldland syndrome” (Khalil et al., 1999; Linde et al., 1994;

Table 2
Effects of different soil treatments on pine seedling shoot and root biomasses

Treatment (soil)	Above ground dry mass (g)	Root fresh mass (g)
1. Plantation	60.70 c	133.23 a
2. Oldland	95.97 a	141.77 a
3. Oldland+ soybean	91.61 a	144.05 a
4. Oldland+ weeping love grass	73.44 b	58.81 b
5. Oldland+ weeds	57.87 c	54.38 b

Means followed by the same letter within each column not significantly different at $P \leq 0.05$.

Noble and Schumann, 1993; Schumann and Noble, 1993). Noble and Schumann (1993) suggested that increased competition for N resources might be the primary cause of poor pine seedling establishment on former agricultural lands. This was partly supported by our findings, which showed that heights of pine seedlings were increased and their aboveground biomass were not depressed where grown in mixtures with soybean, a N fixing species, on the oldland soils. The release of the N from the decomposing soybean material (Nair, 1993) presumably had a beneficial effect on the growth of the pine seedlings, this evident during the later stages (last 3-months) of the trials. Mycorrhizal associations also contribute to nutritional uptake and it has been reported that those allied with *P. patula* seedlings are inhibited in the presence of aqueous extracts of the weed *C. esculentus* L. (Bezuidenhout, 2001). The significantly lower biomass produced by pine seedlings on plantation than oldland soils was not readily explained. One possible explanation was the presence of residual allelopathic compounds in these soils.

The observed reduction in stem diameter and height of pine seedlings grown on the oldland soils in the presence of the weedy species assortment concurred with similar observations by Smith (1989) on *P. taeda* and Nilsson (1994) on Scott's pine cultivated in weedy plots. This reduction was accompanied by increased branching, a common symptom of the 'oldland syndrome' (Leibnitz personal communication)¹ resulting in less robust plants with an undesirable stature for commercial exploitation. The diminished root biomass observed in pine seedlings grown on the oldland soils in the presence of the weedy species assortment also conformed with reports of reduced root development in *P. patula* seedlings cultivated on oldlands (Korf et al., 1997). This feature and the reported inhibition of the ectomycorrhizal species *Boletus maxaria* isolated from *P. patula* roots by allelochemicals in aqueous extracts of the weed *C. esculentus* (Reinhardt et al., 1999; Bezuidenhout, 2001) may partly explain the poor establishment of pines in weed infested fields.

In contrast, growth of the weedy species assortment was unaffected by the presence of soybean or weeping love grass which contrasted with the reported up to 71% reduction in weed mass grown in the presence of soybean (Murphy and Gossett, 1981), the observed poor establishment of the weed *Solanum ptycanthum* in the presence of soybean (Quakenbush and Andersen, 1984), and the reported suppression of weedy species by Sudan sorghum and Italian ryegrass (Burgos and Talbert, 1996).

In conclusion, this study demonstrates the weed suppressive potentials of soybean and weeping love grass, and their applicability as companion or nursing plants for improving establishment and growth of *P. patula* on oldlands. However, weeping love grass, which displayed the most superior weed suppressive capacity might not entirely be suitable as a companion species to *P. patula*, since it did also inhibit pine seedling root growth. The added advantage of utilizing soybean

as a companion crop is that it may assist in raising revenue for local communities thereby alleviating poverty and contributing to employment.

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